Specification and evaluation of substation automation systems

Information from Cigré

The goal of the Cigré working group B5.18 was to provide guidelines for the preparation of such specifications and to furnish supporting information and methods for the evaluation of the different offers submitted by the bidders.

These recommendations for preparation of specifications are based on the experiences of utilities and supported by the research and development of the suppliers. Those for the evaluation itself are derived from the experiences of some utilities.

A sustainable specification for substation automation shall ideally be prepared in such a way that it is focusing on functionality, performance, reliability, evaluation, project management and services to ensure a fair participation and evaluation of the bidders.

Technical requirements

Basic technical requirements

The basic technical requirements are the minimum that is required to describe a substation automation system, and shall ensure that bidders have all necessary information to provide a proper offer covering the needs of the buyer.

This basic technical description shall at least cover the following, areas:

- Functional requirements
  - system functions
  - supervision functions
  - control functions
  - protection functions
- Performance requirements
- Environmental and EMC requirements
- Reliability/availability requirements

Information management

In addition to the local functionality at the substation level itself, the substation automation system in most cases also needs to provide information for users outside the substation. Depending on the targeted user, the type and amount of information that needs to be provided varies. Two main areas for information management can be identified:

- Integration of SA with network control
- Provision of data to remote users such as:
  - protection engineers
  - operational and maintenance centres
  - planning and asset management centres

System architecture

A typical system architecture is divided into three levels:
- process level
- bay level
- station level

Depending on the actual application area, the system architecture might be one with single communication and just a single gateway at the station level, or it might be a system with full redundancy at all three levels.

Fig. 1 illustrates one example of an architecture based on IEC 61850. It shows the architecture with logical connections. The allocation of functions to devices is not defined herein.

The main characteristics of an IEC 61850 based system architecture are:

- Openness due to IEC 61850 and other industrial standards like Ethernet, OPC, etc.
- Seamless 100 Mbps Ethernet structure
- Interoperability defined by IEC 61850
- Client server architecture
- Bay interlocking/automation is independent from station level
- Optional functional redundancy of HMI and station computer
- WEB based test and diagnosis at bay level

Impact if IEC 61850

To be able to answer the question: “What is the impact of the standard IEC 61850 on the specification of n substation automation systems?”, it is important to understand the basic features of IEC 61850.

These are:

- Coverage of all communication needs in the station, i.e. only by both the so called station bus and process bus.
- No specification of functions but the provision of a data model for the functions and their communication needs i.e. it does not block the future development of functions.
- Support of free allocation of functions to devices i.e. it is open for different system philosophies.
- Definition of Ethernet as layer 1 and 2 of the ISO/OSI reference model i.e. it provides the wide range of features of mainstream communication.
- Provision of the substation configuration description language (SCL), i.e. it supports comprehensive consistency in system definition and engineering.
The consequences of the features of the IEC 61850 standard therefore are:

- The functions have to be specified same as before i.e. independent of the use of IEC 61850.
- It has to be decided whether the selection of devices is left to the supplier or is limited by some pre-selection of devices homologated by the utility.
- Availability figures or failure scenarios have to be discussed to get the most appropriate communication architecture.
- The environmental conditions have to be specified very much the same as before but some of these conditions might be decisive criteria for the selection of the communication architecture and, especially, of the communication media e.g. copper cable or glass fiber.
- If the switchgear including the CTs and VTs already exists, its given type of process interface is important information for the substation automation specification.
- If the process interface can be selected (conventionally hardwired or serially linked) this might have some important impacts on the optimization process for the solution to be offered.

**Project management and services**

The project management and service part of a specification covers the aspects that go beyond the technical specification.

**Engineering phase**

During the engineering phase, the following milestones are very important and have to be agreed upon between the manufacturers and users:

- Finalising the project time schedule.
- Defining the interfaces and delivery boundaries to other systems (primary switch car, separate relays, remote control system) is important, especially if those systems come from different manufacturers than the substation automation system. The new IEC 61850 standard will probably help to solve this present problem in substation automation projects.
- Completion of single line diagram, including position of the different objects (CTs, VTs, isolators, etc), which is the basis for the engineering work.
- Acceptance of the main pictures at station level such as single line diagram, event list, alarm list.
- Acceptance of the lists of events and alarms (including their names) with the indication of the particular signal to be sent (station event list, remote, etc.)
- Approval of the cubicle layout.

**Deployment phase**

This part of the specification only concerns substation refurbishment projects that have to deal with more severe erection constraints compared to new substation projects.

The aim is to establish an erection strategy for substation automation systems in existing, energised substations that have the target to:

- minimize outages
- minimize operational constraints
- minimize software and site engineering work

This provides a safe and cost effective approach. Many tools and methods are likely to achieve the goals, such as:

- configuration flexibility of the system
- quality of the utility site data inputs (site diagrams, site information)
- various “software” tools, avoiding less efficient and less reliable ‘hardware’ wiring, and cabling tasks or minimising additional hardware and interface costs during on site erection (temporary interposing relays, etc.)

**Acceptance tests**

Acceptance tests are intended to verify that the substation automation system is in conformance with functional, technological and performance specification, that it is free from failures and operates as intended. The acceptance test also provides a security for both the customer and the supplier. The tests are also confirming that both parties are in agreement on the functions and facilities, that are included.

The test results are approved and a report signed by a representative of the customer. Signing of the test reports does not absolve the supplier from any of his responsibilities during the guarantee period.

The acceptance tests can be grouped into three different categories:

- type test
- factory acceptance test
- site acceptance test

**Table 1**: Acceptance test matrix.

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Type test</th>
<th>FAT</th>
<th>SAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological conformity test</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance tests</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Functional conformity tests</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commissioning tests</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

The basis for the evaluation process is established at the customer specification phase. At this stage, the utility is defining the technical and functional requirements for the equipment, system and services, as well as for the project management. Both basic (mandatory) and optional requirements for the system may be set. Already at this stage, it is also important and necessary to determine tangible performance requirements and weighting factors for intangible attributes.

The second stage of evaluation is carried out when utilities are selecting between tendered systems. The selection will be made between those tendered systems that fulfill the mandatory requirements of the specification by taking into account the quality of the supplier and the cost. In a more enhanced evaluation process, the economy over the total system lifetime is calculated, which includes added values as well as a lifecycle cost and risk analysis. Both tangible and intangible aspects must be evaluated. Tangible items can be quantified in financial or technical performance terms. By contrast, intangible issues cannot be quantified. However, they might be used to support decision making or to prioritize between different solutions.

It also makes sense to check the status on the quality assurance and project plan. Inspections shall be carried out during tests. Based on hold and witness points indicated in the test plan, this inspection will provide information and confidence as to the quality of the tests, and reduce the risk of failure during factory acceptance tests or site acceptance tests, with all potentially related costs and problems thereof.

**Services**

Services shall cover all items that are needed by the customer to enable him to run and maintain the delivered system. The areas covered by services are:

- contractual aspects
- warranties
- penalties
- training
- documentation
- maintainability
- extendability

**Weighting of requirements**

energize - December 2007 - Page 28
The costs and benefits are case dependent and thus it is not possible to provide any numerical values for the weighting factors, but the basic steps of an evaluation process can be described as follows.

**Fulfilment of requirements**

The first step is to check whether or not the tendered systems are fulfilling the requirements defined in tangible terms. In this phase it would be convenient to have already clarified beforehand (in the specification), which of the requirements are mandatory and which issues are negotiable.

**Project-specific items**

The second basic issue is the evaluation of project-specific items to see whether it is possible to carry out the project according to the preliminary plan. This includes the analysis of risks, critical time schedules, reliability of the supplier as well as of the project plan for engineering, factort acceptance tests, erection, commissioning and site acceptance tests.

**Economy-related items**

The third set of issues is economy related: price and commercial conditions including delivery terms, terms of payment, warranty conditions, etc. The various commercial conditions must be valued so as to equalize the tenders. Present worth analysis, levelled costing, or some similar method of putting present and future costs on a comparable basis will have to be used.

The minimum requirement in cost comparison is to calculate the total capital cost instead of the pure quoted price. All costs of design, equipment, software, installation, testing, training, etc. for both the substation automation system supplier and the customer must be included. In some cases also the investment cost of the communication links outside the substation may have to be included.

In a more comprehensive calculation, the life cycle cost (LCC) including the investment cost, added values, operation and maintenance costs are determined. In this calculation, the expected life time of an substation automation system, especially compared to that of the primary equipment, is one important parameter. Also, the time period for which the cost should be calculated must be stated (this could be different from the expected life time). Lifecycle cost is in itself a good measure for the overall performance of a substation automation system, if all cost components can be included. The problem is, that the calculation of LCC is more or less an estimation with many uncertainties. However, when we are comparing different solutions, absolute figures are not that important.

Added values should at least be calculated for the optional functions and new features offered. This should be straightforward if the tender states separate prices for these, but these functions are more often included in the basic system of the supplier without any additional cost. In this case, a bonus could be added based on the financial evaluation of the added functionality as compared to the evaluation results of more conventional types of solutions.

**Qualitative evaluation**

The fourth step is the qualitative evaluation of those aspects for which it is difficult to assign an economical value. One way of avoiding qualitative evaluation is to convert attributes to criteria. In many cases this is not very convenient and it is more practical to use qualitative measures i.e. to weight the different performance aspects of the systems by means of a scoring system. Weighting factors may be different from case to case, depending on the type, location and importance of a substation. If qualitative measuring is used, it is fair to predefine the selection criteria and weighting factors: Qualitative evaluation can be used to support decision making, especially if the systems compared have rather similar investment and/or life cycle costs.

**Overall value**

The final step is to find the highest overall value taking into account both the economical and qualitative evaluations. The quantitative (economical) and the qualitative values must first be scaled with a chosen proportion between the scales, providing an opportunity to put emphasis on either one of these aspects and then perform a scalar or vectorial addition.

While performing the evaluation, either economical or qualitative, it should be remembered that in order to achieve the overall benefits from the utility’s point of view, the cost of substation automation systems and other related information technology based systems, SCADA, etc. might increase. Effective utilization of data also requires stronger use of condition based maintenance and asset management concepts. The main conclusion here is that substation automation systems should not be evaluated as independent units but as a part of the utility’s other operations.

**Conclusion and recommendations**

When preparing a specification for substation automation, it is very important to have a proper structure that covers all requirements of a customer in terms of functionality, performance, availability and efficient project management. To be able to make a proper evaluation of the different offers, the requirements in the specification should be easy to measure and to compare. Thus a simplified structure with clear, straightforward requirements will help to provide an optimal link between the customer’s needs and the evaluation procedure.

There are different ways of considering the new global standard IEC 61850 in the specification of substation automation. The preferred way is to focus on the functionality and to define the station bus without defining further details on the protocol implementation itself. When including more details concerning IEC 61850 in specifications, it is important that the basic features and limitations of the standard are clearly understood. There is also a risk that too many details might jeopardize the efficiency of the project execution due to a focus on the bits and bytes rather than on functional and related system issues.

The weighting of the requirements and the evaluation of the different offers should take into account all aspects that are relevant for a project. The base is given in the customer’s specification, but apart from this, other factors also need to be considered, like economic related items and qualitative evaluation. It is also important that in the evaluation the substation automation system is considered as part of the utility’s wider operations. In the end, the highest overall ranking of all items assessed and weighted during the evaluation process should be used for the comparison of all offers.

In addition to this executive summary, the full report of Cigré working group B5.18 provides significantly more detailed information and guidelines to support the writing of specifications and the evaluation of offers for substation automation systems submitted by bidders.

**Acknowledgement**

This article was published in the August 2007 issue of Electra, the members journal of Cigré, www.cigre.org, and is republished with permission.

Contact Clive Burchell, Cigré, Tel 011 896-3661, ceburchell@telkomsa.net